Bayesian Detection of Climate Signals

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A Bayesian formalism for detecting climate signals is explored analytically and applied to finding the solar cycle in the surface temperature record. Bayesian statistics is well suited to the detection problem because it fully utilizes prior information, such as the predicted amplitude and pattern of a climate signal, in conjunction with a variety of data set to arrive at a posterior probability y of detection. The first level of Bayesian inference gives the same result as optimal fingerprinting, bearing the properties of selective filtering for different possible signals and optimal weighting of the data to suppress the climate variability. Also, the first level of inference generalizes easily to inclusion of the temporal structure of the signal. The second level of inference, which is not accessible to "orthodox" statistics, evaluates how well an ensemble of model predictions explains the data. The result is a relative rating of the climate models in which both the *accuracy* and the *precision* of models are rewarded. It is proven that overly complex models are less relatively probable than simpler ones.

The solar cycle was detected in the surface temperature record with a signal-to-noise ratio of unity. This detection utilizes the temporal structure of the solar cycle signal. Without a predicted uncertainty of the solar cycle amplitude in the surface temperature record, it is impossible to relatively rate models; however; after subtracting four fitted climate signals from the data, the residuals remain much larger than climate model prescriptions of the expected natural variability. The coupled and mixed layer GFDL models perform better than the ECHAM1/LSG model and a simple energy balance model, though. The misfit of the residuals to the model-prescribed variabilities is attributable to either (1) faulty climate signal shapes, (2) the presence of an unknown signal, or (3) an underestimate of the variability y of surface temperature fluctuations by models.

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